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Feeding preference in juveniles of *Acipenser naccarii* Bonaparte 1836

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Summary

The objective of these experiments was to determine juvenile sturgeon (*Acipenser naccarii*) ability to capture live prey as well as to determine their feeding preferences when born and raised in captivity and fed on manufactured feeds until the commencement of the experiment. The purpose was to improve their nutrition and to aid in the development of restocking programmes. For the experiment, one non-adapted group (A) and one group (C, control) previously adapted for 10 days to live feed were used; each group comprised eight similar-age sturgeon (16 fish in total). The experiment was repeated four times for each specimen in group A (A1 to A4) and twice for each in group C (C1 and C2). Using aquaria of 40-L capacity in each experiment, each fish, in isolation, was provided with three individuals of each of the 12 prey categories tested. The number of attacks, differentiating between successful and unsuccessful, were counted, and the elapsed times until the first and third successes were measured together with the type of prey taken. During the course of the experiment, there was a significant reduction in the number of times required to achieve both the first and third successes, as well as a significant increase in the number of successes with time. Preferred prey were those of the worm type (Tubificidae and Lumbricidae).

Introduction

Given the interest in this 'new species', determining its feeding preferences would be useful both for improving its nutrition in cultivation and for the development of restocking programmes (Domezain et al., 1999). As data are not currently available from specimens in the wild, this experimental design proposes what could be termed a 'cafeteria-style' menu selection. The objective of these trials was to study both the feeding preferences and the ability to learn to capture natural food in a favorable artificial medium, in fish hatched and raised in captivity and fed on manufactured feeds until the commencement of the experiment.

Material and methods

In order to determine the potential acceptability of various prey available in a natural medium to juvenile specimens of *Acipenser naccarii*, the fish were offered food resources normally available in the rivers of the Iberian Peninsula; many of these resources were already detected in the diet of this species in natural feeding conditions (Soriguer et al., 1999). Live prey selected included: Gammaridae, Lumbricidae, Tubificidae, Erpobdellidae, Baetidae, Sphaeriidae, Moitessieridae, Lymnaeidae, post-larvae of *Carassius auratus*, and eggs of *Oncorhynchus mykiss*. Also selected were pieces of *O. mykiss* muscle tissue one day (fresh piece of trout) and three days after death (old piece of trout).

Specimens and equipment used were two lots, A and C, *A. nacarii* of 3.5 months of age, F_1 hatched in the Piscifactoría de Riofrío (Granada, Spain) from wild parents captured in the basin of the River Po and housed in the Piscifactoría of Orzinuovi (Brescia, Italy); each lot consisted of eight individuals, with a mean total length of 13.15 (12–14) cm and a mean weight of 11.025 (8–14) g.

Lot A individuals were taken from the cultivation tanks 12 h before commencing the experiments and kept in a first holding aquarium in total absence of food.

Lot C, the control individuals, were kept for 10 days before commencing the experiments in a second holding aquarium. They were fed with the same 12 types of prey that were to be utilized later in the experiment and under the same experimental conditions.

The holding aquaria in which the two lots were held separately were 40.77-L ($52 \times 28 \times 28$ cm) capacity, each with a constant water temperature of 21°C, containing a bed of fine gravel to act as a filtering substrate, with natural vegetation from the Riofrio River and with aeration.

The experimentation aquarium was of the same capacity and the same constant water temperature of 21°C, but without gravel or vegetation; it was also kept aerated.

At the start of the experiment, three specimens of each of the 12 prey types tested were introduced and dispersed manually in the experimentation aquarium. One individual sturgeon was then manually introduced, at time t_0. The time taken by the fish to attack a specific type of prey was measured, together with the success or failure of the capture attempt. The time elapsed until the first capture (T1E) as well as the number of attempts required to achieve this capture (N1E) were noted. The process continued to be timed and recorded until the third capture of any type of prey (time: T3E; number of attempts: N3E) was achieved. The fish was then removed manually from the aquarium and transferred to a third identical holding aquarium. The three specific items of prey that had been consumed were replaced, the second individual sturgeon was introduced and the experimental procedure was repeated. When the procedure had been completed for all eight individuals in succession, first of lot A, then the eight individuals of lot C, the fish were returned to their original separate holding tanks for each lot. This process of 16 successive individual experiments was repeated four times on four successive days for lot A (A1, A2, A3 and A4), and twice on two successive days for lot C (C1 and C2).

Statistical treatment included linear logarithmic models, together with an analysis of variance (ANOVA), taking as variables the time and the number of attacks required to capture the first and the third prey specimen, respectively. Successive comparisons were made of the four repetitions performed with lot A (A1, A2, A3 and A4), of the two repetitions of lot C (C1 and C2), and finally of the six repetitions of lots A and C together. The Statgraphics™ Plus 5.0 (1999) software was employed for these analyses.

Results

In experimental group A, the percentage of successes, independent of prey type, increased from 28 to 67% (Fig. 1); the mean time taken to make an attempt decreased over the four repetitions (A1 to A4) (Fig. 2). In control group C, the percentage of successes remained very similar (62 and 59%) (Fig. 1), as did the mean times (1.3 and 1.0 s) (Fig. 2).

On comparing the mean times taken to make the first attempt (T1), a clear reduction can be seen between group A1 and the rest (A2–C2); this was significantly different (ANOVA $F = 44.36$, $P = 0.000$, multiple range test 95%), whereas there was no significant difference in comparisons among groups A2 to C2.

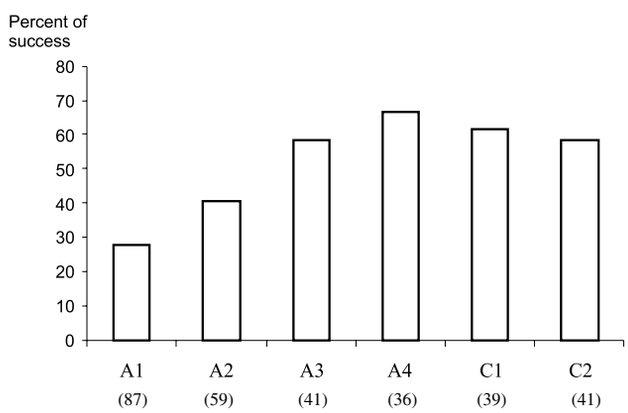

Fig. 1. Progressive success in prey captures, independent of prey type, in each trial series conducted with lot A (A1 to A4) and lot C (C1 and C2). Percentage refers to the number of attempts of each lot (in brackets)

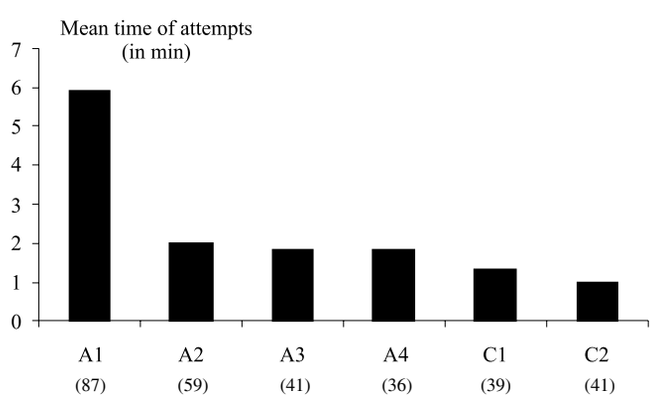

Fig. 2. Progressive improvement in feeding attempts, independent of prey type, in each trial series conducted with lot A (A1 to A4) and lot C (C1 and C2), expressed as mean time in minutes taken to make an attempt (the number of attempts of each lot in brackets)

On performing an analysis of variance for the variables T3E and N3E for the experimental series (A1 to A4), significant differences were observed (ANOVA $F = 56.74$, $P = 0.000$ for T3E and $F = 26.23$, $P = 0.000$ for N3E). Significant differences were also found on performing an analysis of variance for the variables T3E and N3E, for all the series of trials (A1 to C1) (ANOVA $F = 69.19$, $P = 0.000$ and $F = 19.34$, $P = 0.000$, respectively).

On comparing the times taken to achieve the third success (T3E), there were significant differences between the groups. In particular, there was a considerable reduction in the time taken to capture the third prey between the first group of experiments (A1) and the rest of the groups (A2–C2), and although a reduction in T3E was found over the course of the experiments with the other groups (A2–C2), there was a significant difference only between A2 and C2 (Multiple Range Test 95%). On studying the relationship of T3E against T1E for the four experimental groups (A1–A4) by means of Simple Linear Regression, a clear relationship exists ($R^2 = 89.01\%$); however, if experiment A1 is excluded, this significant regression disappears ($R^2 = 13.18\%$). A similar situation is found in comparing the number of attempts, without taking the prey type into account. In the full experimental series (A1 to C2), a significant reduction can be seen between group A1 and the rest (A2 to C2) (ANOVA, $F = 10.24$) for the number of attempts required to achieve the first success (N1E), whereas comparing the third success (N3E), significant differences are seen between groups A1 and A2, and the rest (Multiple Range Test 95%). In the first series of experiments (A1 to A4), for the total of 96 successes measured there were also 128 failures, making an overall total of 224 attempts to capture prey. The four types of prey most often attacked were: Tubificidae with 56 attempts (25% of the total attempts) of which 40 succeeded (42% of total successes), Lumbricidae with 54 (24%) attempts of which 36 (38%) succeeded, Erpobdellidae with 39 (17%) attempts of which 11 (11%) succeeded, and Gammaridae with 33 (13%) attempts of which 1 (1%) succeeded. The remaining types of prey were each attempted less than 18 times; there were no attempts made to capture the post-larvae of *C. auratus* or the trout eggs. (Fig. 3a and b).

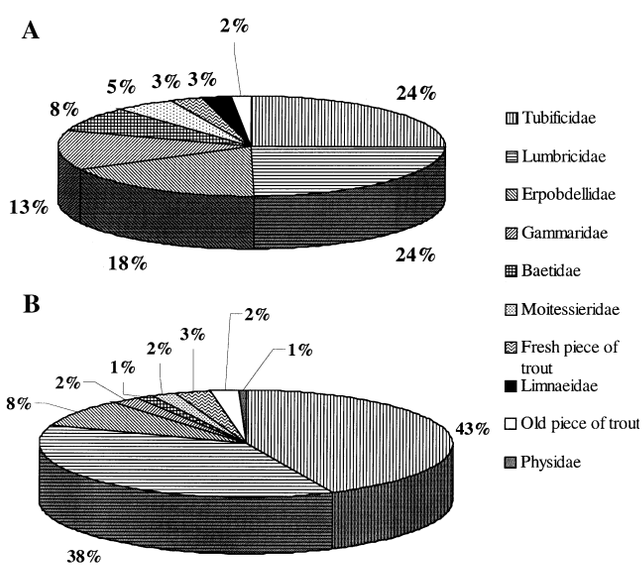

Fig. 3. Food preference measured as the percentage of total attempts (n = 303) on each prey type (A) and as the percentage of successful attempts (n = 144) on each prey type (B)

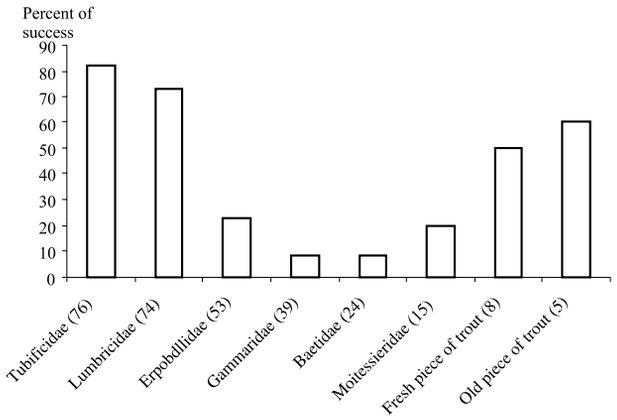

Fig. 4. Relative feeding success for various prey types, expressed as percentage of the total number of attempts on that prey type (in brackets)

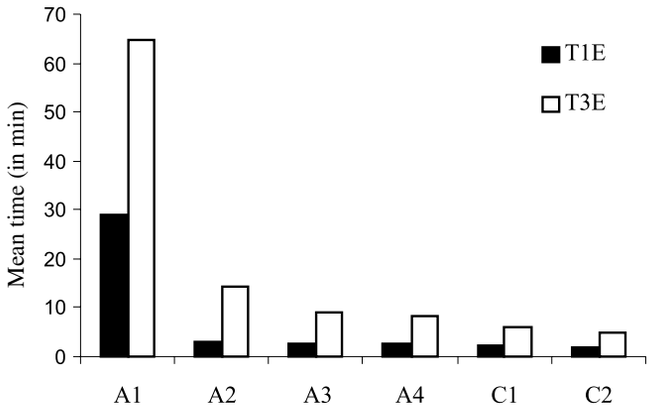

Fig. 5. Rate of learning: mean time required (in minutes) to capture the first prey (T1E) and the third prey (T3E) in each successive trial of the eight individuals of lot A (A1 to A4) and of lot C (C1 and C2)

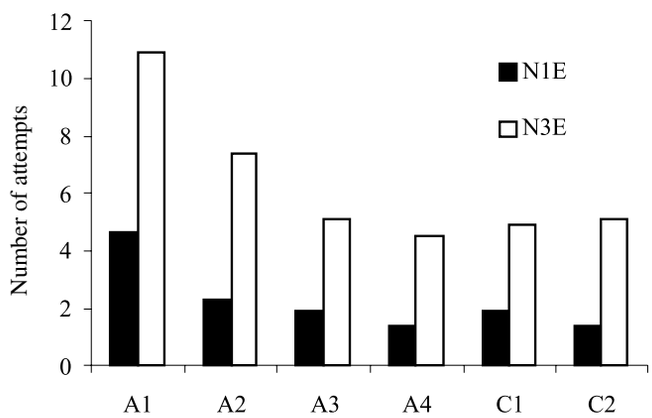

Fig. 6. Rate of learning: number of attempts needed to capture the first prey (N1E) and the third prey (N3E) in each successive trial of the eight individuals of lot A (A1 to A4) and of lot C (C1 and C2)

In respect of the overall ability of sturgeon to capture prey (Fig. 4), the four types of prey most easily captured, measured as the percentage of successes over the total number of attempts on that type of food (lots A1–A4) were: Tubificidae with 82%, Lumbricidae with 73%, and the pieces of trout tissue (with 60 and 50%).

Discussion

The results demonstrate that, over the course of the experiments, there was a clear reduction both in the time required to capture food (Fig. 5) and in the number of attacks or attempts needed to capture the prey (Fig. 6). The success rate increase shows that during the experimental period the fish were learning to capture live prey more rapidly; this was evident to the greatest degree between the series A1 and A2 – the first and second repetition. During the experiment, the non-adapted specimens of lot A attained a level of capability, in terms of times required for the capture, very close to that of the control group (lot C) that had spent 10 days undergoing prior adaptation. However, it cannot be stated that during this time the sturgeon had reached the learning threshold.

The time elapsed until the first successful capture (T1E) and the number of attempts required to achieve this (N1E) turned out to be less informative than the time and number of attempts required for the capture of the third prey specimen (T3E and N3E, respectively). It is believed that this is due to the period of learning required by the sturgeon to adapt to the disposition and movement of prey within the aquarium.

Both in the analysis of mean time elapsed in achieving the three captures recorded for each lot of eight sturgeons, and in the mean number of attempts required for this achievement, a clear reduction is observed in the series A1 to A4; the reduction is much less notable from C1 to C2. This is assumed to be due to the 10 days prior learning undergone by the latter specimens, as described previously. On comparing the data of the full set of series from A1 to C2, again a clear trend toward reduction can be seen, with a point of inflection in the reduction rate between the third and fourth repetition.

These results indicate that a preference existed for Tubificidae and Lumbricidae. Over the course of the experiment, no evidence was found that relative size differences among the various prey types was a limiting factor. A rapid increase was observed in the ability of the sturgeon to capture the preferred prey, but the maximum success rate may not have been achieved in this experimental period. At present, the authors are unable to state the reasons why these types of prey were preferred since diverse factors were involved (prey mobility and defensive capacity, fish learning capacity, organoleptic characteristics, etc.) which cannot be discriminated with this experimental design. It was observed that no attacks were made on live fish prey, but there were some attacks made on fish remains in two different stages of decomposition; this is in agreement with the results of Bernini and Nardi (1991) and Soriguer et al. (1999) in the preference for worm-type prey.

Acknowledgements

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